AD-A274 522

(2)

AUTOMATED FABRIC INSPECTION SYSTEM

FINAL REPORT - PHASE I

A Short Term Research and Development Task
Proposed Under DLA900-87-D-0017
Delivery Order 0018

30 January 1990 - 15 May 1993

Principal Investigator:

Dr. Christine W. Jarvis
AAMTD Project Director
Clemson Apparel Research
500 Lebanon Road
Pendleton, SC 29670

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	October 1, 1993	Final - 1/30/90 - 5/15/93

4. TITLE AND SUBTITLE

"Automated Fabric Inspection System"

5. FUNDING NUMBERS

DLA900-87-D-0017 DO 0017

6. AUTHOR(S)

Dr. Christine W. Jarvis

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Clemson Apparel Research
500 Lebanon Road
Pendleton, SC 29670

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Defense Logistics Agency
Camerson Station
Alexandria, VA 22304-6100

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

The Automatic Fabric Inspection System developed by Systronics Inc. for Clemson Apparel Research uses vision technology to acquire images of the fabric two thousand times per second. Each image - video line consisting of 2048 picture elements is analyzed by a signal processing module and a decision on defect presence and location is made. A product norm signal is first established by having the system acquire an image of an unflawed stripe of the product. The output of each picture element (pixel)is digitized to a grey scale value in the 0 - 255 range. Threshold levels for defects with grey scale values higher and lower than product norm can then be established and set. The system will then compare all subsequent images against the set thresholds.

14. SUBJECT TERMS

grey scale, images

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std. Z39-18
298-102

CONTENTS : PAGE

1. INTRODUCTION	2
2. THEORY OF OPERATION	3
3. THE SYSTEM DESIGN	4
4. INSPECTION SETUP PROCEDURE	5
5. RUN MODE OPERATION OF THE SYSTEM	8
6. EXPERIMENTS CONDUCTED AT CAR	
6.1 EXPERIMENT 1	9
6.2 EXPERIMENT 2	12
7. DIFFICULTIES ENCOUNTERED DURING EXPERIMENTATION	14
8. SCOPE AND LIMITATIONS OF THE SYSTEM	15
9. CONCLUSION	16
10. APPENDIX Systronic Eagle Diagrams	17

EXECUTIVE SUMMARY

The Automatic Fabric Inspection System developed by Systronics Inc. for Clemson Apparel Research uses vision technology to acquire images of the fabric two thousand times per second (2000 Hz). Each image - video line consisting of 2048 picture elements, is analyzed by a signal processing module and a decision on defect presence and location is made. A product norm signal is first established by having the system acquire an image of an unflawed stripe of the product. The output of each picture element (pixel) is digitized to a grey scale value in the 0 - 255 range. Threshold levels for defects with grey scale values higher and lower than product norm can then be established and set. The system will then compare all subsequent images against the set thresholds.

In a typical application, images are acquired perpendicular to the warp direction and represent thin stripes of material across the filling. Successive video lines are merged to form a large two dimensional image of the fabric. The system generates a signal when a defect is detected. Defect data are reported to a monitor, printer, RS232 port, and/or diskfile.

High speed vision technology such as used in the Automatic Fabric Inspection System represents a new approach to textile fabric inspection. However, the classes of materials which may be inspected are currently restricted to grey goods and lightly colored uniform materials. Multicolored and nonuniform materials produce images with high noise levels degrade the detectability of signals from many types of defects. The system performs best in applications where the fabric is uniform (low noise) and where defects have maximum contrast with the acceptable part of the fabric. Current limits of defect detectability is a 0.05 inch defect at 120 feet per minute for defects with high contrast to the fabric such as a dark spot on a white fabric.

Further developments in fabric lighting should widen the range of fabrics which can be inspected with this technique.

1. INTRODUCTION

The conventional method used to detect weaving and grey defects in textile products is visual inspection by the machine operators and quality control personnel. Inspection normally occurs off line, i.e, after production, where the product can be rewound over a light plate thereby enhancing the defects visual characteristics for easier detection. Only flaws on the "face" surface of the fabric and visible from about three feet are considered defects. The inability of the human eye to detect small (<0.5") defects moving at high speeds limits this kind of inspection to 75 - 100 feet per minute fabric speed. Even at this speed, defect such as slubs, endouts, and small holes can easily pass undetected. This project is an investigation and development of an alternative means of inspection.

The fundamental principle incorporated in this project is the variation of light intensity reflected by differently colored materials. For instance, it is known that dark colored materials reflect less light intensity incident on them than brighter materials. The idea here is that a uniform, flawless strip of fabric, would reflect light of uniform intensity and any flaw that is present would reflect a significantly

different level of light. A bright flaw such as a double threading would reflect more light than the flawless product. A dark flaw such as a dye spot would reflect less light than the flawless product. Such information when stored electronically yields an accurate flaw map of the fabric strip. Similar technology is being used successfully for inspection of materials such as plastics, polyethylene, and bearings. Back lighting of the product and transmitted light are generally used in the above applications although.

Phase - 1A of the project involved development of the hardware and software for the inspection system. This task was subcontracted to Systronics Incorporated, Atlanta. Specifications were provided by CAR and the progress was constantly monitored throughout the subcontract. Employees of CAR were trained to operate the system at the end of this phase. Phase -1B of the project consisted of building a camera stand, mounting the light source on a fabric winder and performing tests on the inspection system. This phase was designed to estimate the capabilities and limits of the system and was conducted at the CAR workshop. This report is the summary of the entire Phase I effort.

Section 2 describes the theory of operation of the system. Section 3 is a brief description of various components of the system. Section 4 describes a setup procedure for inspection by the system. Section 5 describes an actual inspection run. Section 6 describes various experiments conducted at CAR, the results obtained, and the analysis of results. Section 7 describes some problems that were encountered during the experiments. Section 8 analyzes the scope and limitations of the inspection system.

2. THEORY OF OPERATION

The automated fabric inspection system captures video images of winding fabric several hundred times per second. Each camera module (an eye of the system) has a linear array made of 2048 cells or picture elements (pixels). These cells convert the reflected light from the fabric into electric charge. Periodically, charges accumulated by these cells (buckets) are drained and converted into voltages. These voltages are then digitized to gray scale values in the 0-255 range. Each video line, composed of 2048 gray scale values, is then analyzed by a signal processing module and a decision on the defect presence and location is made. A product norm is first established by having the system acquire an image of an unflawed strip of the product. Threshold levels for defects with gray scale values higher and lower than the product norm are then established and set.

Flaw sizes and locations are established by the system in pixel coordinates. For instance, if two pixels 100 and 101 of a camera generate gray scale values exceeding the product norm, then the system makes a decision that it has found a bright flaw of width 2 pixels, 100 pixels into its field of view. Such pixel coordinates are converted into physical coordinates (in inches) before being displayed to the operator. This conversion is made possible by establishing the field-of-view (fov) or the width of fabric seen by the camera. The flaw map associated with fabric rolls are reported to a monitor, printer, and/or a disk file.

Before proceeding to the next section, brief descriptions of some commonly used terminology's are presented :

Field of View (FOV) : The width of fabric (which may also include the background) that is to be inspected by the camera module. Though the camera can inspect using all its 2048 pixels, the inspection is usually restricted to some range between pixel 0 and pixel 2048 for accuracy.

Resolution : The size of the smallest defect that could be identified by the system for a particular setup. Resolution depends upon the distance of separation between the camera and fabric. If a camera spans a width of x inches using all of its 2048 pixels, then its resolution is computed as x/2048.

3. SYSTEM DESIGN

The automated fabric inspection system consists of:
a) Four 5 M Hz camera modules.
b) Four signal processing modules.
c) One central computer (Central).
d) One 19" high resolution color monitor with touch screen.
e) One 6' light box with red fluorescence output.
f) One encoder.
g) One alarm light.
h) Assortment of cables.
i) Interactive software.

Cameras

Cameras are used by the system to acquire images of the fabric. Standard Cannon series 50 mm lenses are used to focus the images on line scan sensors housed in the camera boxes. The sensors are Charge Coupled Devices (CCD) with linear arrays of 2048 pixels. An onboard pixel clock operates at 5 M Hz allowing for a maximum scan rate of 2400 images/second.

Signal (video) Processing Modules

These modules are the "slave computers" of the system. Each module analyzes the video line received from its associated camera, and outputs information about defects if any are present. Also, each module keeps track of the web flow from the encoder input and determines the down web (Y direction) location of defects. A menu driven software provides a variety of signal processing algorithms and operating parameters. Calculations and analysis done by these modules are performed in pixel coordinates and encoder pulses. Results and operating parameters are communicated to and from the Central via a serial port. Signals to the alarm light are also generated from these modules.

Central

Central provides the operator interface (OI) for the system. The control software is run on an AT compatible (80386 sx/ 20 M Hz) computer (the Central). Flaw data from each vision module is translated from pixel and encoder dimensions to web coordinates and then displayed. Inspection parameters, roll information, and system commands can be entered from the touch screen or keyboard. Roll reports and disk files are generated by the Central. An RS 232 port is available for external serial interfacing.

Light source

The light source is a 6' high frequency fluorescent light box. It is used to illuminate a strip of the rolling fabric; the reflected light is trapped by the cameras to obtain a uniform image of the strip.

Software

The system has a menu driven software that provides a variety of signal processing algorithms and operating parameters. This software is executed on the central and is responsible for the generation of roll reports and disk files.

4. INSPECTION SETUP PROCEDURE

Before the inspection system can be used in detecting flaws in fabric rolls, it has to be setup for proper video acquisition. The setup procedure requires an oscilloscope. Camera modules for inspection are setup one at a time. The setup software is first initiated by naming the vision module (**setup a** is an example). The basic steps undertaken for setup are listed below :

a) Fabric roll is wound on the winder.

b) The light box is adjusted (rotated) so as to illuminate a strip of fabric on the roller, at a suitable angle of incidence '*a*'. The angle of incidence is usually about 15 to 30 degrees below an imaginary horizontal plane cutting through the strip of fabric. The angle is fine tuned later for maximizing the intensity of reflected light.

c) The camera stand is positioned at about the same angle *a* as in step b), but above the horizontal plane looking downward.

d) The oscilloscope is connected to three BNC connectors in the system corresponding to the camera module being setup (A, B, C or D). The system and the oscilloscope are powered on, and the setup software on the PC is executed.

e) The line rate of the inspection module is set to 1000 in the software. The horizontal time base (time/div) on the scope is set so as to view a single line of video. This is usually about (0.1/line rate) seconds/div.

f) Using suitable selection in the software (menu 66), the raw video of the fabric is displayed on the scope. The raw video estimates the effectiveness of the lighting and camera setup. A good raw video corresponding to the uniform fabric is about one volt on the scope. Raw video appears as an inverted image on the scope (i.e. -1 volts). Any dark spot on the line of inspection would appear as a negative voltage, closer to zero than that of the uniform fabric. A bright spot, on the other hand would be a negative voltage, farther away from 0 than the fabric.

Parameters and adjustments that affect the raw video are :

1) Line scan rate : Lowering this parameter causes the light sensor to be charged for a longer duration before the charge is drained to the image processor. Thus lowering line scan rate increases the video signal level.

2) Light source and camera orientation with respect to the line of inspection. : The cameras have to be very finely positioned so as to capture maximum reflected light from the fabric.

3) Distance between the camera and fabric : As the distance increases, the intensity of light trapped by the lenses decreases. Also, the width of the fabric covered by a single pixel increases, thereby decreasing the ultimate sensitivity of the system to defects

4) Focus of the Camera (aperture adjustment).

These parameters are fine tuned until the raw video obtained is satisfactory.

g) Parameters such as stage 1 offset, stage 2 offset, gain average, side gain, edge gain and the smile center are adjusted to refine raw video of step f). The smile center is of special importance. The video captured by the camera lens is usually of higher intensity at the center than toward the edges. This is because of the physical curvature of the lens. Smile center in coordination with side and edge gains can be used to reduce the gain at the center and increase it to the sides, so as to make the video uniform. At this point, the scope is made to display the processed video. A good processed video is about 2 volts on the scope and is positive in magnitude.

h) Processed video is then displayed on the monitor of the system by selecting menu 46. Video on the monitor is about 128 gray scale in magnitude for the uniform product. A dark spot on the line of inspection must be seen as a dark fall in video reaching 0 gray scale. A bright spot must be seen as a bright spike in video tending toward 255 gray scale level. If this is not the case, parameters in step g) have to be altered slightly to produce the desired effect.

i) Parameters have to be set now to inform the image processor about the upper and lower bounds of video for the uniform product. The upper bound (threshold high) is an indication to the system that any video signal above this level within

the field of view is a bright flaw. Similarly, the lower bound (threshold low) is an indication to the system that any video below this level within the field of view is a dark flaw. These levels are set according to the flaw detection needs of the operator. For instance, if one does not want to tag minute flaws, these levels must vary significantly from the level of uniform product. On the other hand, if the operator desires to detect minute flaws, this range must be narrowed accordingly.

Another parameter called the product threshold (or product norm) has to be set at this time if the camera is viewing any of the product edges. This value is in between the gray scale value of the uniform product and 255. This is an indication to the image processor that any video larger than product threshold close to 0 or 2047 pixel is the shiny roller (background) and not a bright flaw. Parameters such as Background Bright, Left_Edge_Moving and Right_Edge_Moving are set according to the lighting scheme and whether the camera is seeing any of the product edges. These parameters can be set in screen 68.

j) The field of view of the camera for inspection range is now established. This procedure can be done using the scope. Once we know the outer limits of the camera's vision across the width of fabric, we can set the range that is to be inspected as desired. For example, if the camera sees 4 inches of shiny roller to the left edge of the fabric and 10 inches of fabric (a total vision of 14 inches), we may not want the system to inspect a width of 1 inch on either edge of the width of vision. This may be because of the irregularity in the video signal toward the edges. In that case we set the field of view of the camera so as to inspect only 12 inches inside the actual view. This setup is done as follows :

14 inches width ---------------> seen by 2048 pixels (0 through 2047)
1 inch width ---------------> seen by (1 * 2048)/14 = 146.3 pixels
(150 pixels approximately)

Thus we have to set Left_Field_Of_View = 150 pixel and Right_Field_OF_View = 2047 - 150 = 1897 pixel.

k) Parameters have to be set in screen 68 to classify flaws according to size and intensity. For instance, an operator may require that the smallest flaw to be spotted by the system be at least 2 pixels wide and 2 pixels long and be classified as a medium dark flaw.

l) The working parameters have to be stored in the EPROM for later use. This is done by getting into menu 45 and typing "ZZSYSTRONICS" followed by a carriage return. CTRL Z quits this screen.

To use multiple cameras to increase resolution, steps a) through l) have to be repeated. Care has to be taken for overlapping fov's of each camera properly. For instance, if camera A uses its pixels 50 through 2000 to inspect first half of the fabric width, camera B has to be adjusted so as to continue the inspection from where A terminated.

The following section describes actual inspection by the system in run mode.

5. RUN MODE OPERATION OF THE SYSTEM

Once the setup procedure for inspection has been completed, the software for real time inspection of the winding fabric has to be executed. This exists as clemson.exe in the PC. This program first scans the system to see which of the four processing modules are active. It then generates a status report on the screen. The inspection menu is then initiated by a touch of the screen. Before the actual inspection, the mapping of pixels to physical coordinates and the division of width of inspection into zones has to be performed. These are done as follows :

Pressing CTRL K displays the supervisor options button on the touch screen. Touching this button displays another screen. The Engineer options button has to selected now. This displays yet another screen of options. Here the option for setting camera coordinates has to be selected. Let us assume that three cameras are being used for inspection, each inspecting 15 inches. Let us assume that the total fabric width is 40 inches and camera A inspects 2.5 inches of shiny roller to the left and camera C inspects 2.5 inches of shiny roller to the right. A camera coordinate setting may look like :

Module	Coord (Inches)	Start Pixel	Coord(Inch es)	End Pixel
1	0	20	15	1900
2	15	100	30	2000
3	30	75	45	1980
4	0	0	0	0

These values were actually determined in step j) of setup procedure.

Now, on returning to engineer menu, suitable buttons can be selected and values set so as to divide the inspection width into logical zones before flaw report is generated. This procedure is useful for grouping flaws according to their cross web distances. These values have to be stored to a disk file for reuse. Once this step is completed, we can return to the supervisor options screen and enable printer if a printout of defects is desired.

This step completes the initialization for an actual inspection run. A check is made to see if the down web encoder is placed correctly on one of the rollers in the fabric winder. The software in now returned to menu level 1. The roll reset button is clicked and the fabric winder is turned on after the desired speed is set.

The Central screen now shows down web and cross web coordinates of the flaws on the fabric as it winds. It also sorts the flaws according to their logical cross web zones inside the width of the fabric. Flaws are classified according to their intensity and size using the parameters that were preset during setup procedure. The operator is now free to attend to some other task while the inspection system is busy identifying and mapping flaws. The operator can return at some

anticipated time to turn off the winder and stop inspection by the system. The following section describes a set of experiments used to estimate the effectiveness of the inspection system.

6. EXPERIMENTS CONDUCTED AT CAR

6.1 EXPERIMENT 1 :

Aim : To repeatedly inspect the same portion of a fabric at varying speeds of the winder and estimate the accuracy of the system using the variance of the number of flaws detected and their actual physical coordinates.

Procedure : Three of the inspection modules A, B and D were setup to inspect about 8 feet length of a fabric roll. Camera A inspected 15.14 inches using pixels 130 through 1704. This setup included the left edge of the fabric roll and shiny background to the left. Camera B inspected 18.75 inches using pixels 67 through 1987. This setup did not include the background. Camera D was used to inspect 16.95 inches using pixels 154 through 1935. This setup included the right edge of the fabric roll and shiny background to the right. The total field of view of inspection was 50.84 inches wide. The modules used the following working parameters for inspection :

	Camera A	Camera B	Camera D
Left_FOV	130	67	154
Right_FOV	1704	1987	1935
Stage1_Off	130	100	100
Avg_Gain	65	55	75
Side Gain	70	40	65
Edge_Gain	0	0	0
Smile_Center	1050	700	1200
Stage2_Off	120	100	100
Thresh_High	185	195	195
Thresh_Low	55	30	30

Background Bright was set to true for Module A and D and was set to false for module B which did not see any edge. The line rate for all the three modules were set to 1000. The system was then made to inspect the same 8 feet length of fabric repeatedly at four different speeds; 15, 30, 60 and 120 feet/minute. The inspection was divided into four logical zones; 0 to 15 inches, 15 to 30 inches, 30 to 45 inches and finally 45 to 50.84 inches.

Data :

All Down Web (warp) distances are in feet and Cross Web (filling) distances are in inches.

Run 1 : Speed = 15 feet/minute

Flaw Num	FlawType	Lane	Down Web	Cross Web	Length	Width
1	MedDrk	2	0.0	21.3	0.17	0.05
2	MedDrk	1	0.6	10.6	0.02	0.05
3	MedBrt	1	0.6	11.7	0.02	0.16
4	LargeDrk	2	0.6	18.3	0.23	0.27
5	MedDrk	3	0.7	37.2	0.11	0.03
6	MedDrk	1	1.5	7.9	0.05	0.04
7	MedBrt	1	1.7	6.2	0.04	0.13
8	MedDrk	3	1.7	45	0.07	0.04
9	LargeDrk	2	3.9	24.2	0.95	0.10
10	MedDrk	1	6.1	4.9	0.05	0.16
11	LargeDrk	2	8.0	23.4	0.36	0.32

Run 2 : Speed = 30 feet/minute

Flaw Num	FlawType	Lane	Down Web	Cross Web	Length	Width
1	MedDrk	2	0.0	21.3	0.04	0.03
2	MedBrt	1	0.6	11.6	0.02	0.30
3	LargeDrk	2	0.6	18.3	0.23	0.28
4	MedDrk	3	0.7	37.2	0.11	0.03
5	MedDrk	3	0.7	45.0	0.06	0.03
6	LargeDrk	2	3.9	24.2	0.98	0.12
7	MedDrk	1	6.1	4.8	0.05	0.14
8	MedDrk	1	8.0	6.8	0.04	0.06
9	LargeDrk	2	8.1	23.0	0.36	0.34

Run 3 : Speed = 60 feet/minute

Flaw Num	FlawType	Lane	Down Web	Cross Web	Length	Width
1	MedDrk	2	0.0	21.3	0.13	0.03
2	MedBrt	1	0.7	11.6	0.02	0.30
3	LargeDrk	2	0.7	18.3	0.24	0.27
4	MedDrk	3	0.7	44.9	0.06	0.04
5	MedBrt	1	1.7	6.1	0.01	0.17
6	LargeDrk	2	4.0	24.2	0.91	0.12
7	MedDrk	1	6.2	5.0	0.05	0.13
8	MedDrk	1	8.1	7.2	0.04	0.06
9	LargeDrk	2	8.2	23.4	0.35	0.32

Run 4 : Speed = 120 feet/minute

Flaw Num	FlawType	Lane	Down Web	Cross Web	Length	Width
1	MedDrk	2	0.0	21.3	0.26	0.06
2	MedBrt	1	0.7	11.7	0.01	0.17
3	LargeDrk	2	0.7	18.4	0.22	0.27
4	MedDrk	4	0.7	45.0	0.07	0.03
5	LargeDrk	2	4.1	24.3	0.95	0.11
6	MedDrk	1	6.3	4.9	0.01	0.12
7	MedDrk	1	8.1	7.1	0.01	0.04
8	LargeDrk	2	8.2	23.3	0.35	0.34

Observations :

It was seen that the system identified and mapped flaws less than 0.05 inches in length and width very accurately. This claim was verified by manual measurements of size and downweb-cross web coordinates. Flaws smaller than 0.05 inches were detected when the fabric was wound at the speed of 15 feet/minute. It was also observed that a medium bright flaw at down web distance 1.7 that was detected in run 1 was undetected in run two. Surprisingly the same flaw was detected in run 3 which was at 60 feet/minute. A medium dark flaw was detected at down web distance of 8.1 feet in runs 2, 3 and 4 but went undetected in run 1. Slight differences were seen in the down web distances of flaws in different runs.

Analysis :

The discrepancy in detection of medium bright flaw at down web distance 1.7 feet could be attributed to the improper tensioning mechanism in the fabric winder. The medium dark flaw at down web distance can be eliminated from analysis as it is at the end of the eight feet length of the inspected fabric. Inpection in run 1 might have been terminated before this flaw could actually pass through the line of inspection. The variations in downweb distances of flaws can be attributed to the uneven rotation of the fabric winder and hence that of the attached down web encoder.

6.2 EXPERIMENT 2 :

Aim : To repeatedly inspect the same portion of a fabric at varying speeds of the winder with same settings as in experiment 1 but this time using noise suppression algorithm.

Procedure : The settings were similar to that of experiment 1 but for minor changes. The upper and lower thresholds for each of the inspection modules were narrowed by 5 gray scales. Set Freq Low and Set Freq High were set to 2. The same length of fabric was once again inspected at four different winder speeds.

Data :

All Down Web (warp) distances are in feet and Cross Web (filling) distances are in inches.

Run 1 : Speed = 15 feet/minute

Flaw Num	FlawType	Lane	Down Web	Cross Web	Length	Width
1	MedDrk	2	0.0	21.3	0.12	0.04
2	MedBrt	1	0.6	11.6	0.04	0.38
3	LargeDrk	2	0.7	18.3	0.25	0.28
4	MedDrk	3	1.7	44.9	0.06	0.04
5	MedDrk	1	1.7	7.8	0.04	0.04
6	MedBrt	1	1.7	6.1	0.04	0.22
7	MedBrt	1	2.5	3.0	0.02	0.09
8	LargeDrk	2	3.9	24.3	1.01	0.12
9	MedDrk	1	6.3	5.0	0.06	0.16
10	MedBrt	1	6.5	7.5	0.02	0.06
11	LargeDrk	2	8.3	23.4	0.37	0.34

Run 2 : Speed = 30 feet/minute

Flaw Num	FlawType	Lane	Down Web	Cross Web	Length	Width
1	MedDrk	2	0.0	21.3	0.07	0.05
2	MedDrk	1	0.6	10.7	0.02	0.06
3	MedBrt	1	0.6	11.6	0.02	0.26
4	LargeDrk	2	0.6	18.4	0.24	0.28
5	MedDrk	4	1.7	45.1	0.06	0.04
6	MedDrk	1	1.7	4.3	0.05	0.03
7	MedDrk	1	1.8	8.0	0.05	0.04
8	MedBrt	1	1.8	6.3	0.02	0.14
9	MedDrk	1	6.3	4.9	0.06	0.16
10	LargeDrk	2	8.2	23.2	0.35	0.34
11	MedDrk	1	8.3	7.0	0.12	0.07

Run 3 : Speed = 60 feet/minute

Flaw Num	FlawType	Lane	Down Web	Cross Web	Length	Width
1	MedDrk	2	0.2	21.3	0.07	0.03
2	MedDrk	1	0.8	10.6	0.02	0.05
3	MedBrt	1	0.8	11.6	0.02	0.30
4	LargeDrk	2	0.8	18.3	0.23	0.27
5	MedDrk	3	0.9	37.2	0.08	0.03
6	MedDrk	3	1.8	44.9	0.06	0.05
7	MedDrk	1	1.8	7.8	0.05	0.04
8	MedBrt	1	1.9	6.2	0.01	0.13
9	LargeDrk	2	4.1	24.2	0.97	0.11
10	MedDrk	1	6.3	4.8	0.05	0.15
11	LargeDrk	2	8.2	23.2	0.35	0.33

Run 4 : Speed = 120 feet/minute

Flaw Num	FlawType	Lane	Down Web	Cross Web	Length	Width
1	MedDrk	2	0.2	21.3	0.26	0.05
2	MedBrt	1	0.8	11.5	0.02	0.38
3	LargeDrk	2	0.8	18.3	0.23	0.27
4	MedDrk	3	0.8	45.0	0.05	0.04
5	MedDrk	1	0.9	7.8	0.01	0.04
6	MedBrt	1	1.8	6.3	0.01	0.05
7	LargeDrk	2	1.8	24.3	1.0	0.12
8	MedDrk	1	1.9	5.0	0.01	0.14
9	LargeDrk	2	4.1	23.5	0.34	0.34
10	MedDrk	1	6.3	7.3	0.10	0.07

Observations :

It was seen that more bright flaws were detected in experiment 2 than in experiment 1. It was also seen that The total number of flaws detected in experiment 2 was a constant for the four different runs, unlike experiment 1. Variations in downweb distances were present as before.

Analysis :

The improvement in performance can be attributed to the use of a noise suppression algorithm and narrowing of the threshold levels. The Set_Freq_High and Set_Freq_Low parameters prevent the system from mistakenly identifying image noise as fabric defects. Thus they allow the operator to narrow down the threshold levels further to increase the accuracy in detecting minute flaws. Thus more number of tiny bright flaws were detected in this experiment than in the previous experiments.

7. DIFFICULTIES ENCOUNTERED DURING EXPERIMENTATION

Some difficulties that were encountered during the experiments conducted at CAR are listed in this section. Corrective measures that were adopted for some of these difficulties are also presented wherever applicable.

The camera stand had the following design flaws :

a) Physical stability was not taken into account in the design of the camera stand. When multiple cameras were used for inspection, the weight of cameras leaning to the front was not properly coupled at the rear of the stand. There was a potential danger of the entire camera mount toppling to the front accidentally on

application of minor force. This situation was temporarily rectified by placing two heavy concrete slabs at the base of the camera stand.

b) It was also seen that after having setup one camera for proper focus, adjustment to a second camera disturbed the previous setup. This was because of the weight of the bars supporting the cameras and tightening mechanism which required application of a lot of force. A better design of the camera stand would be to fix all the cameras on a single plate and provide the flexibility for minor adjustments.

The fabric winder had the following flaws :

a) Faulty air guides in the system caused the fabric to wander to one side even when wound at very low speed. This motion confused the system when the fabric wandered so much that the shiny roller to one side was not visible : the system was not able to track one edge of the fabric anymore.

b) When tension was applied to the fabric, the winding became irregular. The winder used to stop all of a sudden and continue later. This prevented the line of inspection from being uniform and gave incorrect down web values when the system was inspecting.

c) The winder did not have the provision to wind the fabric in reverse direction. This defect made the setup procedure and repetive tests difficult.

8. SCOPE AND LIMITATIONS OF THE SYSTEM

The automated fabric inspection system has several powerful features. At this stage of the project, the system is capable of detecting flaws as small as 0.05 inches at high fabric winder speeds as high as 120 feet/minute. The system can presently be used to detect significantly contrasting flaws on fabric rolls. It can be used by fabric manufacturers as a quality control instrument to inspect their products before shipment. Each roll of fabric can be accompanied by a diskette containing the flaw map generated by the inspection system.

The limits of the system at this stage of development are as follows :

1) The system does not detect dark flaws on dark materials.
2) The system does not detect minor shade differences in fabric.
3) The system is not capable of inspecting fabric with pattern design.

These limitations can be resolved by using a different lighting scheme such as back lighting and higher resolution cameras. The system can also be used for tagging flaws on the fabric roll during the process of inspection. This setup requires that a tagging device be interfaced to the fabric winder and the inspection system. The system can also be incorporated with a marker and cutter such that the flaw information could be put to use on the fly. These are the tasks of main interest for the next phase of the project.

9. CONCLUSION

The automated inspection system was successfully tested at CAR. The system implementation was subcontracted to Systronics Inc., and the progress was constantly monitored. The camera stand and the fabric winder were designed by CAR and incorporated with the system. Several experiments were performed to test the limits of the system. *Double threading*, holes, grease spots, dye spots and mispicks were the flaws that were frequently detected by the system with accuracy. A light green military shirt material and several denim fabrics were inspected for defects. Several demonstrations were given to apparel manufacturers and scientists visiting CAR and the response was very encouraging. Finally, it can be asserted with confidence that the system could find its place in the fabric and apparel industry in the near future and would be put to use for several years to come.

10. APPENDIX

Systronics Eagle Diagrams

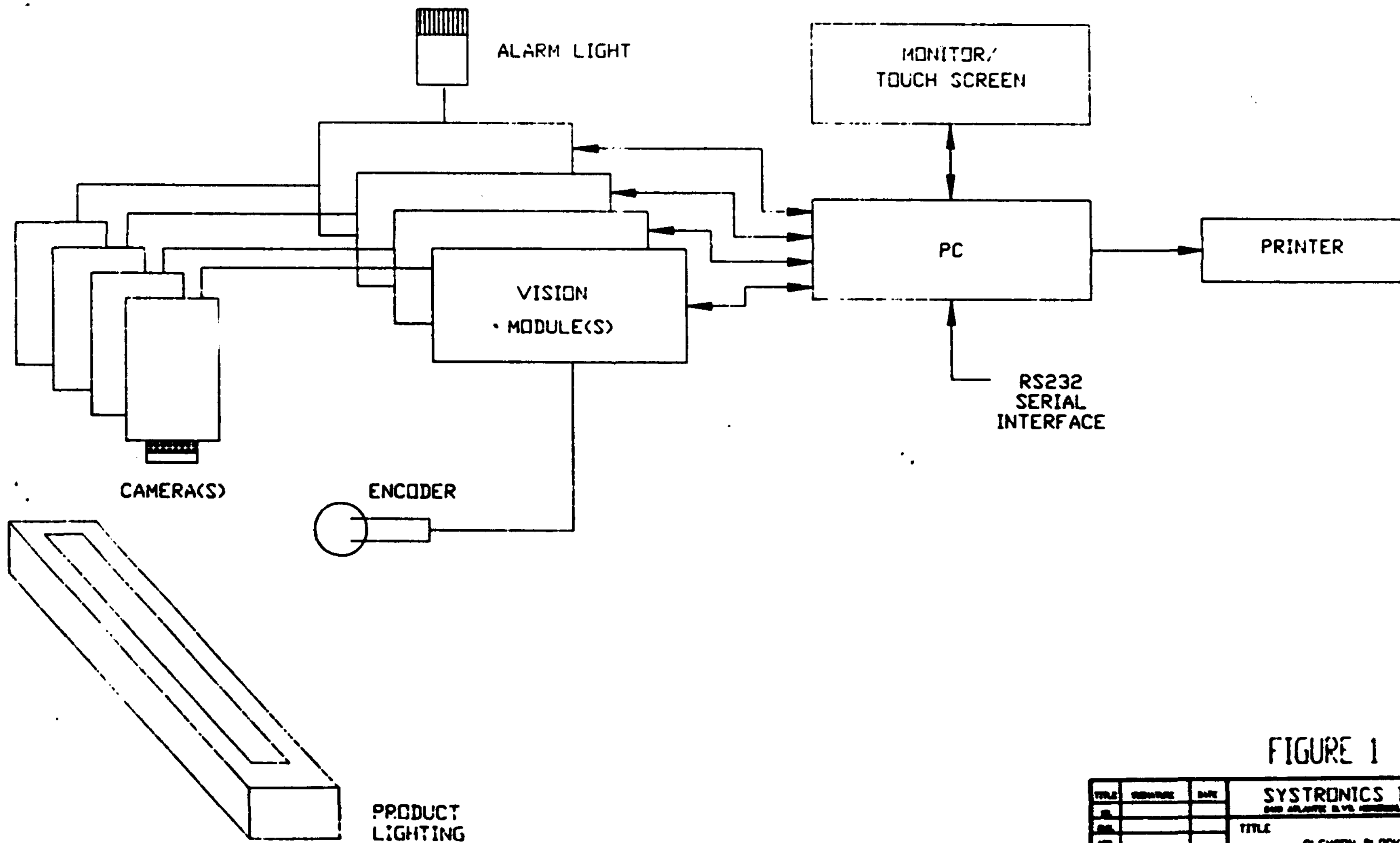

FIGURE 1

SYSTRONICS INC.

TITLE: CLEMSON BLOCK DIAGRAM

FILE NAME: 1410007/CLEMSON

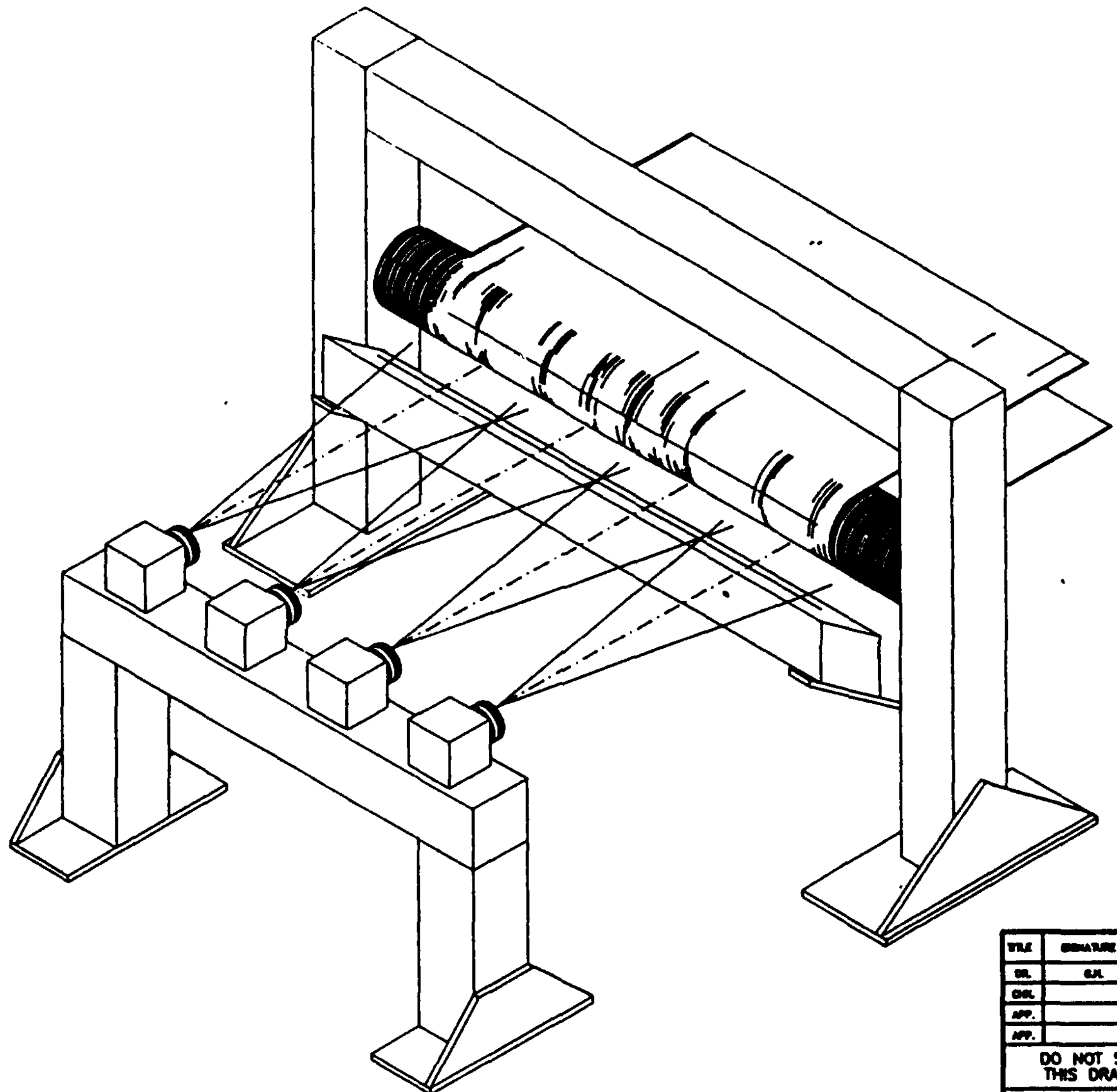

FIGURE 2.

TITLE	SIGNATURE	DATE
DR.	G.H.	11-15-91
CHK.		
APP.		
APP.		

DO NOT SCALE THIS DRAWING

FILE NAME: 1411010/CLEMSON

SYSTRONICS INC.

TITLE CLEMSON

LIGHTING CONFIGURATION

SIZE	DRAWING NO. SHEET 1 OF 1	ISSUE
B	90-141-1010	A